CSD3 Sunshine Duration Sensor

User Guide

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CSD3 Sunshine Duration Sensor

CSD3 is a sensor for measurement of sunshine duration. Sunshine duration is defined as the time during which the direct solar radiation exceeds the level of 120 W/m². The CSD3 provides an estimate of this measurement without the expense or complexity of using a tracking pyroheliometer.

CSD3 is designed for use in agricultural meteorology (evaporation), for tourist information (number of sunshine hours), for building automation (automatic control of sunscreens) and for providing statistical data for health resorts, etc. A two-level switchable heater is fitted as standard which will remove dew, frost and, on the high level setting, even snow and ice, thus giving improved measurements in adverse conditions.

1. Introduction

The CSD3 employs three detectors, each covering part of the sky. The direct radiation is calculated from the difference in signal level. The detectors have exactly the same spectral and angular characteristics, which makes the process of re-calibration very easy.

Great care has been taken to design the angular characteristics of the detector, resulting in a measurement that can be used anywhere on earth in a fixed position, and which does not show any seasonal effects. The CSD3 has no moving parts and a low power consumption.

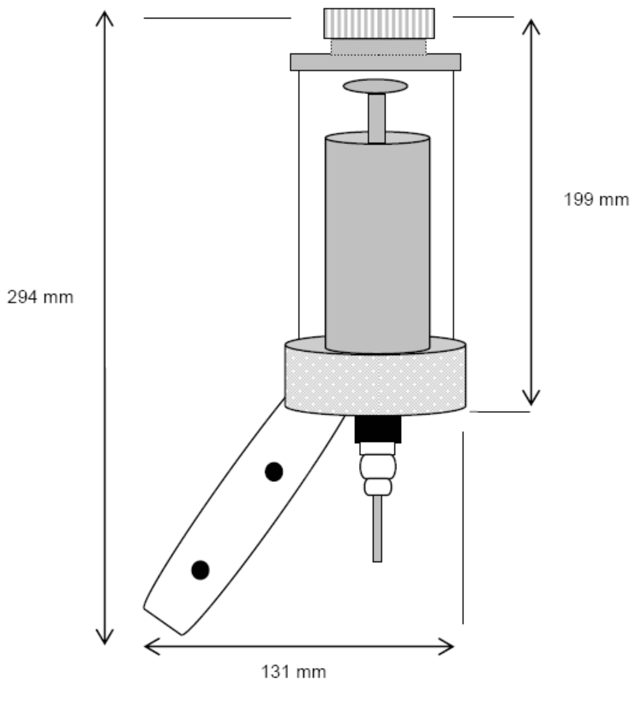

Figure 1 Dimensions of the CSD3

2. Specifications

Measurement accuracy figures shown were determined by experimental direct comparison with reference instruments that are traceable to WRR (World Radiometer Reference) standards. The figures apply to any location world-wide.

Sensor Specifications:

Ambient temperature range:	-30°C to +70°C
Power supply:	
without heater	<10mA (typically <2mA)
with low level heating	1 ±0.1W at 12VDC
with high level heating	10 ±1.0W at 12VDC
Electronics warm-up time:	1 minute
Estimated accuracy:	
Direct solar irradiance	>120 W/m^2 1±0.1V
	<120 W/m^2 0±0.1V
Direct radiation measurement	1mV/W/m^2 ±10% for clear sky
Expected output range	0-1000mV (nominal)
Non-stability	<2% change per year
Temperature dependence	<0.1%/K
Response time	<1 ms
Impedance	1 kΩ
Typical mean error for monthly sunshine hour totals	<±10%
Spectral range:	400-1100nm

Heater Specifications:

Power supply (low level heating)	1 ±0.1W at 12 ±3VDC
Power supply (high level heating)	10 ±1.0W at 12 ±3VDC
Expected heating/temperature range for melting ice/snow:	
Low level heating	(will only remove dew/frost)
High level heating	0 to -15°C, wind speed <1m/s
Thermal switch (optional)	
Heating level 2 on if case temp.	<6°C ± 3°C
Heating level 2 off if case temp.	>14°C ± 3°C

3. Siting and Installing the CSD3

3.1 Choosing a Location

The most suitable location for your CSD3 is obviously in a position where it is exposed to direct radiation from the sun throughout the day. An ‘open’ horizon is best.

For correct installation you will need to know the latitude of the location and the north-south axis. A compass and/or map will assist in determining this.

3.2 Installation

When mounting to a support structure (mast, tower or tripod), mount the CSD3 on the South side of the structure in the Northern hemisphere or on the North side in the Southern hemisphere to reduce the risk that the instrument is shaded by the structure itself.

When viewing from above, the instrument must be mounted on a North-South axis. The angle between the axis of the CSD3 and the horizontal plane should be equal to the latitude of the installation site. This will ensure that the measurements are optimised. See Figures 2 and 3 for further details.

If using a Campbell Scientific CSD3 mounting arm please refer to Figure 2 for mounting details. The multipurpose kit supplied includes extra washers and spacers, some of which will not be required for mounting the CSD3.

Mount the sensor following the guidelines given above and as shown in Figures 3 and 4.

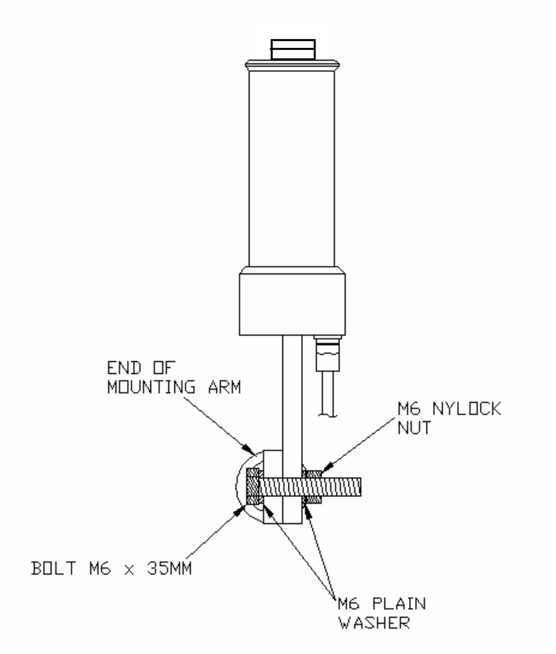

Figure 2 Mounting the Sensor on a CSD3 Mounting Arm

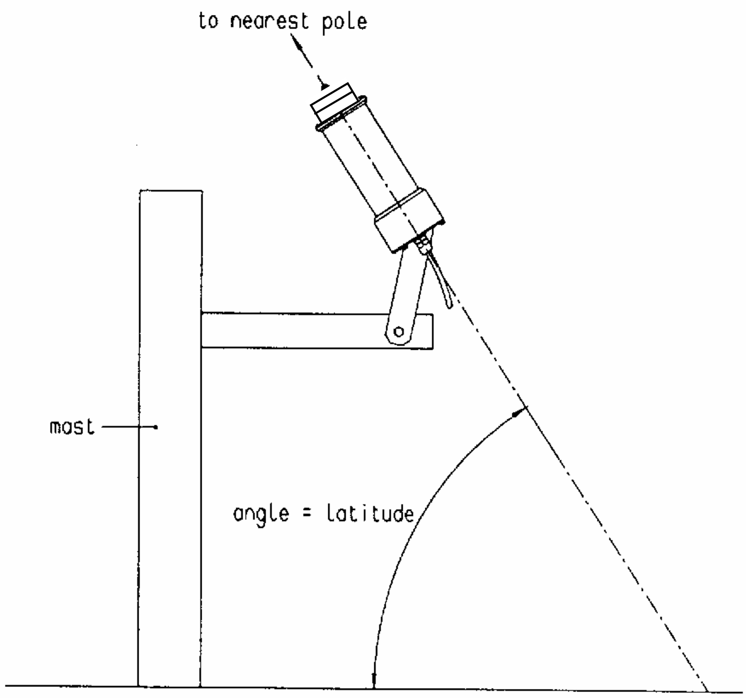

Figure 3 Installation of CSD3 to a Structure

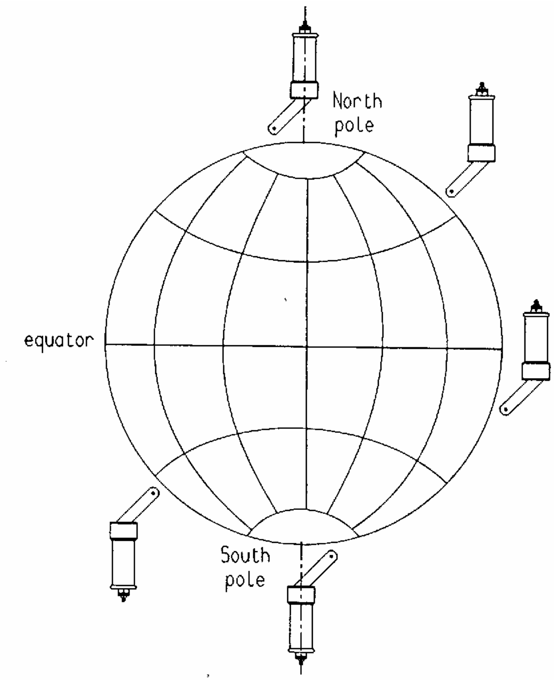

Figure 4 Global View

3.3 Wiring

The following tables show the wiring colour and function for the CSD3's inputs and output.

Wire Colour	Output	Datalogger Connection
red	Sunshine 0/1V	Single-ended input
blue	Signal ground	⏚ ('G' on CR10X)
grey	Direct radiation 1mV/(W/m^2)	Single-ended input, if required

Wire Colour	Input
brown	Power Supply +12V
yellow	Power Supply Ground*

* datalogger power ground symbols – 'G' for CR10X ⏚ for other dataloggers.

Wire Colour	Output (heaters)
white	Supply 10W (high level) heating +12V
pink	Common 10W / 1W heater 0
green	Supply 1W (low level) heating +12V

The CSD3 requires a power supply of 9-15VDC at 10mW (see specifications in Section 2). However, if you wish to use the on-board heaters, you will normally need to supply a separate12V DC supply at 1W (for level 1 heating) or 10W (for level 2 heating). See the specifications, above (Section 2) and Section 4, below.

4. Using the CSD3

When the CSD3 is installed and connected to a datalogger and external power supply (if using the heater), it is ready to take readings.

4.1 Sunshine Duration Measurement

Sunshine duration measurement is usually output as either 1-minute or 1-hourly values or the daily total.

By definition the direct radiation must be more than 120W/m^2 and so the voltage output will be 1V. If direct radiation is less than this figure (i.e. the sun is not shining) the output will be 0.

4.1.1 Example CR1000 program for the CSD3 sensor

```
'CR1000
'Example program for the CSD1/CSD3 sensor

'Declare Variables and Units
Public CSDSig, Suntime

Units Suntime=hours

'Define Data Tables
'In this example there is one table that outputs at midnight
DataTable(Table1,True,-1)
DataInterval(0,24,Hr,10)
'Include the daily total of sunshine hours
Totalize(1,Suntime,FP2,False)
EndTable

'Main Program
BeginProg
Scan(5,Sec,1,0)

      'CSD1/CSD3 Sunshine Duration Sensor
      VoltSE(CSDSig,1,1,1,False,0,250,1,0)
      'If Greater than 500 mV we have sunshine
      'Load the time between scans, in hours,
      'into a variable that can be totalised
      If CSDSig>=500 Then
      Suntime=0.00138
      Else
      Suntime=0
      EndIf
      'Call Data Tables and Store Data
      CallTable(Table1)
NextScan
EndProg
```

4.1.2 CR10X Datalogger Program for CSD3

```
;{CR10X}
;Program example for the CSD3 showing how to use the
;sunshine state output to give total sunshine hours
;per day.

*Table 1 Program
  01: 10.0000   Execution Interval (seconds)

;Measure the sunshine state output
1:  Volt (SE) (P1)
 1: 1        Reps
 2: 5        2500 mV Slow Range
 3: 1        SE Channel
 4: 2        Loc [ CSD3Sig   ]
 5: 1        Mult
 6: 0        Offset

;If Greater than 500 mV we have sunshine
```

```
2:  If (X<=>F) (P89)
 1: 2        X Loc [ CSD3Sig   ]
 2: 3        >=
 3: 500      F
 4: 30       Then Do

;so load the time between scans, in hours, into
;an input location (= 10 sec/3600)
3:  Z=F x 10^n (P30)
 1: .002778  F
 2: 0        n, Exponent of 10
 3: 1        Z Loc [ Suntime   ]

4:  Else (P94)

;Otherwise if the sun is not shining, load zero
5:  Z=F x 10^n (P30)
 1: 0        F
 2: 0        n, Exponent of 10
 3: 1        Z Loc [ Suntime   ]

6:  End (P95)

;Once per day
7:  If time is (P92)
 1: 0        Minutes (Seconds --) into a
 2: 1440     Interval (same units as above)
 3: 10       Set Output Flag High (Flag 0)

;Store the time
8:  Real Time (P77)
 1: 1220     Year,Day,Hour/Minute (midnight = 2400)

;and totalize the suntime location to give a total
;number of hours of sun in the previous day
9:  Totalize (P72)
 1: 1        Reps
 2: 1        Loc [ Suntime   ]

*Table 2 Program
  01: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program

-Input Locations-
1 Suntime   1 1 2
2 CSD3Sig   1 1 1
3 _________ 0 0 0
4 _________ 0 0 0
5 _________ 0 0 0
6 _________ 0 0 0
7 _________ 0 0 0
8 _________ 0 0 0
9 _________ 0 0 0
10 _________ 0 0 0
```

4.2 Direct Radiation Measurement

A signal representing the direct radiation is given as an additional value. The signal will vary with irradiance, equalling 0V when no direct radiation is present. The calibration is factory-set at a nominal level of 1mV/W/m^2.

This output is primarily designed for calibration purposes. It should not be used as a measure of direct radiation because the errors can be up to ±10% at certain sun angles. Campbell Scientific is aware that some meteorological organisations are attempting to use this output with more complex algorithms to improve the accuracy of the sunshine hours measurement. However, no published results are available at this time, and so we are unable to support use of this signal.

4.3 Using the Heater

One of the major error sources in sunshine duration measurement is the obstruction of light by water that is deposited on the instrument. This event, caused by dew, frost or snow, can be reduced by heating the instrument.

The CSD3 on-board heaters can be used at two levels. The heaters are simple high power resistors which will deliver 10W or 1W at a recommended voltage of 12VDC.

Switching from no heating to low level (1 W) or high level (10 W) can be done by using a switch or by an automated relay.

Two PSW12 or other similar solid state relays can be used to allow the datalogger to control the power to the two heaters. These relays can be controlled by the datalogger program, if necessary, both to conserve power and to prevent damage to the sensor (see below). Please contact Campbell Scientific if you need more advice on the required modifications to your program.

As mentioned in section 3.3, it is often better to provide a separate supply to power the heaters from that used by the datalogger. This is because, in the event of a fault in the charging circuit, the extra power required for the heaters will soon drain the standard battery packs used to run the datalogger. If a common supply *must* be used, it is advisable to include code in the datalogger program to shut off the power to the heaters in the event of the battery voltage falling below a preset level, e.g. 12 Volts, thus ensuring the datalogger continues taking measurements for as long as possible.

The low level heating setting will serve to stop dew forming. The high level setting is such that it will melt snow and ice provided that the ambient temperature is not lower than -15°C and wind speeds are less than 1m/s.

It is recommended to use the 10W heater only when it is strictly necessary, as use of this heater at high ambient temperatures could damage the CSD3. At ambient temperatures of more than 10 degrees the heater should be switched off. It is also suggested that the heater is switched off during the night to conserve power. Allow a warm-up period of at least 30 minutes after switching the heater on before starting to take measurements. A longer warm-up time should be allowed if excessive ice or dew formation is likely – for example at sunrise.

5. Calibration

The CSD3 has three detectors. They all have exactly the same spectral and angular characteristics, thus aiding the calibration process. Calibration at the manufacturers is done by comparison with a reference sensor which is traceable to a broadband solar radiation measurement under clear sky conditions.

Re-calibration is preferably done by the manufacturer. However, the resistors for adjusting the sensitivity are accessible so that local calibration can be carried out by suitably qualified personnel.

See Appendix A for full details of the calibration procedure.

6. Maintenance

The CSD3 requires very little routine maintenance, as follows:

1. Clean the transparent window at regular intervals.
2. Check the desiccant (inside the cap on the top of the instrument). If the 40% indicator inside the sensor has turned pink it indicates that it is saturated with water and the desiccant cartridge will need to be replaced..

7. Optical Theory

The optical theory is explained in Appendix B.

8. Troubleshooting

If the CSD3 signal fails, or if you think that you are getting improbable results, please use the following procedures to help correct or pinpoint the problem.

1. Check the location. Are there any obstructions that cast a shadow on the instrument by blocking the direct sun during some part of the day?

2. Check the orientation of the CSD3. The tilt angle should be equal to the local latitude. The top should point to the North in the Northern hemisphere, or South in the Southern hemisphere, to an accuracy better than 10 degrees.

3. Check the instrument's window – it should be clear. If water/condensation is deposited on the inside, please change or dry out the desiccant. If there is a great deal of moisture inside the instrument, it should be thoroughly dried out.

4. If all the above seems OK, check the power supply. The voltage input (between connectors J15 and J16 or J17) should be between 9V and 15V. The input current should be between 0.2mA and 2mA.

5. If the voltage and current are in the correct range, as above, the CSD3 should be opened, by unscrewing the bottom plate, and inspected

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NOTE It is recommended that, before opening the CSD3, it should be transferred to an indoor facility.

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6. Open the instrument and inspect for any damage. If no obvious damage is visible, check the response of each of the detectors to light. With power supply to the CSD3 connected, measure the response of detector D1 to an ordinary desk lamp across pins J18-1 and J18-2. Similarly the response for detector D2 is measured across pins J18-5 and J18-2, and for D3 across pins J18-6 and J18-2. See Figure 5, below.

If any damage or malfunctions are found, please contact Campbell Scientific for advice.

The row of 6 pins besides the centre hole in the PCB is connector J19, and is used for technical servicing purposes only. Pin J16 or pin J17 is ground.

The pin assignments and outputs are shown below. If one or more of the pins differ, please contact Campbell Scientific for advice.

PIN No.	Pin Assignment	Output
1	Output Sunshine Indication	0 = No, 1 = Yes
2	Output Direct Signal	~1mV/(W/m^2)
3	Reference Voltage	Should be 1.115 ±0.003 Volts
4	Should be equal to Pin 2	Output Direct Signal (unbuffered)
5	Stabilised Power Supply	5 ±0.2 Volts
6	Internal Supply Voltage	Should be 1 to 1.5 volts less than power supply voltage

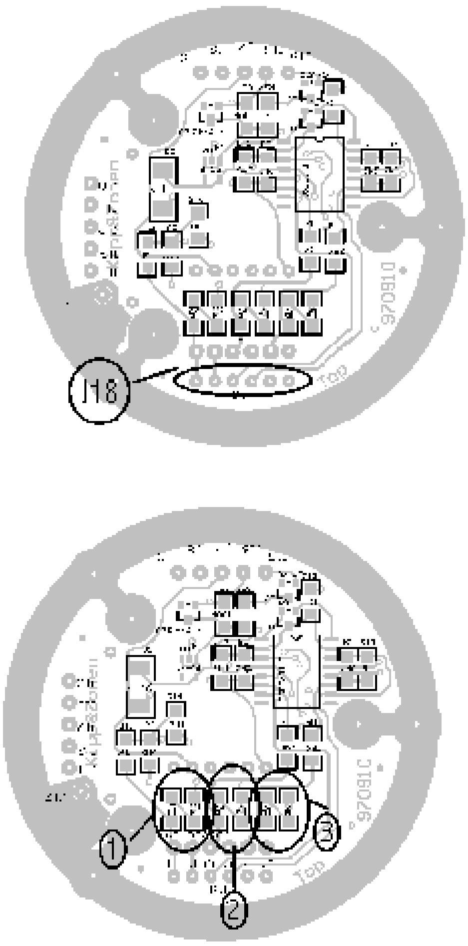


Figure 5 Position of the Calibration Resistors and Connector J18.

Appendix A. Calibration Procedure for the CSD3

It is generally recommended that the CSD3 is calibrated by the manufacturer. However calibration can be undertaken by the end user following the procedure outlined below, to an accuracy of approximately ±5%.

A.1 Introduction

When the CDS3 is returned for calibration by the manufacturer, it is carried out using a pyrheliometer that is traceable to WRR.

If you have a network equipped with CSD3s, it is feasible to do a simplified calibration which can serve for quality assurance purposes. This type of calibration utilises a ‘reference CSD3’ and a solar simulator. The ‘reference CSD3’ simply is a CSD3 which is kept in a dark place and used purely for reference purposes, and so can be considered stable.

The solar simulator can be any kind of beam representing the sun. Some facilities might have a classified solar simulator available, whereas others might utilise a simple slide projector. The beam spectrum should resemble the solar spectrum as closely as possible and have a small opening angle.

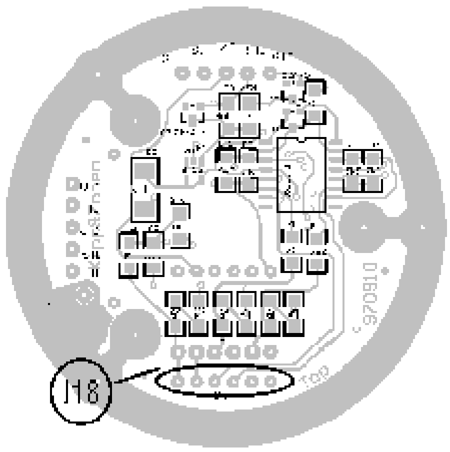
When calibration is carried out by the customer an accuracy of +/- 5% can be attained. The general policy is to adapt the sensitivity of the detectors in the CSD3 only if they show a deviation from the reference that is more than 5%, and to leave things as they are if a deviation of less than 5% is measured.

A.2 Calibration Procedure

1. Install the reference instrument in the beam of the solar simulator, so that the beam covers the entire instrument. If possible the local intensity of the beam should be at around 500 Watts per square metre, and the room temperature at about 20 degrees, although this is not critical.

2. The detector D1 of the reference is always considered to be the reference detector. Take the average reading of J18-1 and J18-2, (see Figure A-1, below) and rotate the CSD3 around its axis to take a total of 4 readings. The average of these readings is called REF1.

The sensitivity of FD1 is adjusted at the factory to 50µW/m^2. This offers the opportunity to check the intensity of the beam. At 500W/m^2, the output voltage should be 25mV.



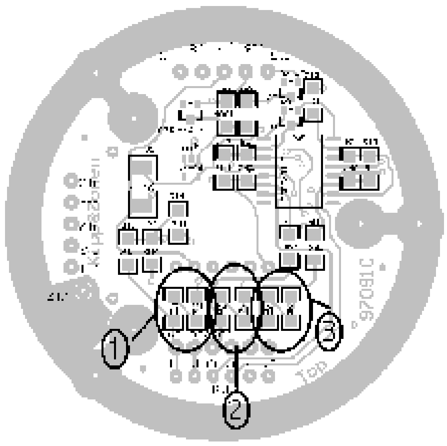


Figure A-1 Position of Calibration Resistors and Connector J18

3. Now take the CSD3 that needs to be checked and put it in the reference position.
4. Take the readings of D1 for the CSD3 at 4 angles (J18-1 and J18-2). The average of these readings is called FD1.
5. Put D2 of the CSD3 in the position of D1. Take the readings of D2 for the CSD3 in 2 opposite directions (J18-2 and J18-5). The average is called FD2.
6. Put D3 of the CSD3 in the position of D2. Take the readings of D3 for the CSD3 in 2 opposite directions (J18-2 and J18-6). The average is called FD3.
7. FD1 should equal REF1. If the deviation is more than 5% it is suggested to replace the resistors at location 1 (RES1) to adjust the sensitivity. The value of the replacement resistors is a function of the existing resistors and the ratio REF1/FD1. First remove the resistors at location 1 and measure their values. The value of the replacement resistors (REP1) can then be calculated according to the following formula:

REP1 = total of existing resistor values * (REF1 / FD1)

NOTE A ‘calibration resistor’ always consists of two separate resistors. The total value can be calculated by adding the two resistance values.

8. FD2 should equal 3.3 times REF1. If the deviation is more than 5% it is suggested to replace the resistors at location 2 (RES2) to adjust the sensitivity. The value of the replacement resistors is a function of the existing resistors and the ratio REF1/FD2. First the resistors at location 2 are removed, and their value is measured. The value of the replacement resistors REP2 can be then calculated according to the following formula:

REP2 = total old resistor value * (3.3 * REF1 / FD2)

9. REP3 can be treated as REP2. The resistors are shown at location 3.

REP3 = total old resistor value * (3.3 * REF1 / FD3)

10. It is recommended to check the result of the replacement by performing a second calibration.

A.2.1 Recommended Resistors

The following gives recommendations for replacing calibration resistors:

Surface mounted type: 1206 ceramic chip type

Resistance tolerance: ± 1 %

Temperature coefficient: ± 100 ppm/ºC

Example of suitable resistors:

Manufacturer : Bourns

Type: Commercial Thin Film Chip Resistor

Series number : 1206

Alumina substrate

Resistance tolerance: ± 1 %

Temperature coefficient: ± 100 ppm/ºC

Power rating: 0.3 W

Appendix B. Optical Theory

B.1 Introduction

The sunshine duration is defined as the time during which the direct solar radiation exceeds the level of 120 W/m^2. The reference measurement of direct radiation can be done using a radiation sensor with a limited field of view (a pyrheliometer) and pointing this towards the sun (typically done using a solar tracker).

The CSD3 is an instrument that is primarily designed to offer a relatively simple way of measuring the sunshine duration. Relative to the standard method, several compromises had to be made. Basically the direct radiation level is no longer determined directly, but deduced from a differential measurement between the signal level of several detectors. Secondly not the full spectrum is measured, but only a part of it.

This philosophy has made it possible to make a sensor that does not require moving parts, and has a relatively low cost. Further considerations for design were:

Low power consumption

Easy to recalibrate

No seasonal effects

Installation at any latitude

B.2 Optical Theory

The way that the CSD3 works is as follows:

Inside the CSD3 are three detectors, D1, D2 and D3. See Figure B-1, below. D1 detects all the solar radiation, direct and diffuse. D2 and D3 cover only part of the sky; the part that is covered by D2 is not seen by D3and vice-versa.

The electronics of the CSD3 first determines whether D2 or D3 is receiving direct radiation (maximum signal). It chooses the detector with the smallest signal, and assumes that this output represents approximately 1/3 of the diffuse radiation. Some corrections, C, for geometry are made (see formula below).

The value of D1 is reduced by the estimated value of the diffuse radiation to give the direct radiation figure.

Direct radiation = D1 - C * (smaller of D2 and D3)

where D1 is the signal of detector D1 etc., C is a corrector for geometry.

The direct radiation signal can be measured at one of the instrument's outputs.

There is a comparison to the 120 W/m^2 level, as recommended by WMO, in order to result in the value for sunshine duration.

Sunshine Duration if Direct radiation > 120 W/m^2 .

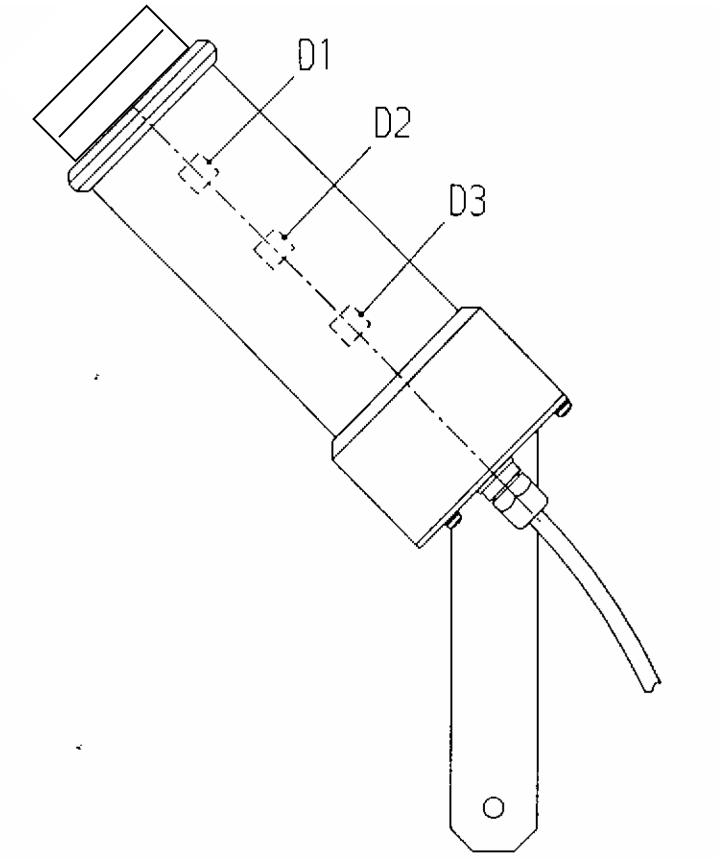


Figure B-1 The CSD3 Showing the Position of the Three Detectors D1, D2 and D3

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